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(54) Recovery of precious metal(s)

(57) A process for recovering, as metal or as a compound thereof, at least one precious metal (e.g. Au, Ag, Pt, Pd) from a solution of at least one dissolved compound of that precious metal, said process comprising:

at least one adsorption stage for adsorbing onto activated carbon at least one precious metal compound from said solution, wherein said activated carbon is in the form of at least one fibrous body comprising fibres of activated carbon so that said fibrous body becomes at least partly loaded with said adsorbed at least one precious metal compound; and optionally in at least one said adsorption stage, at least one said fibrous body has at least one substrate.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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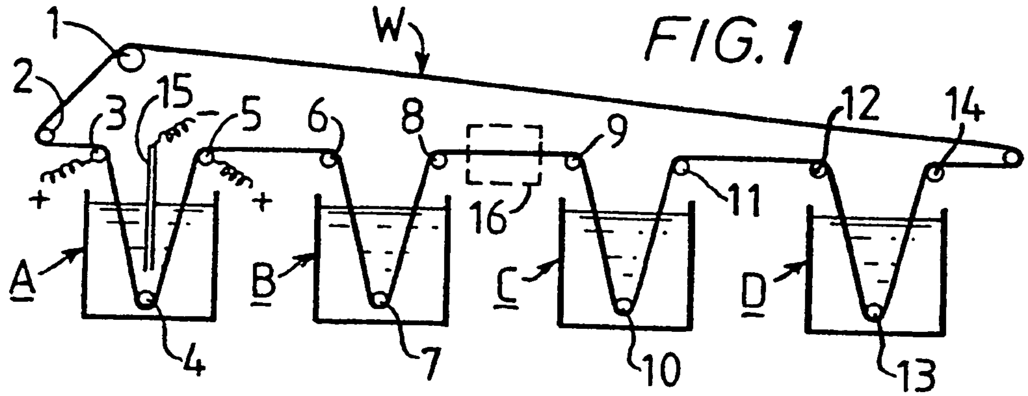
W
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2
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13

FIG. 1

FIG. 2

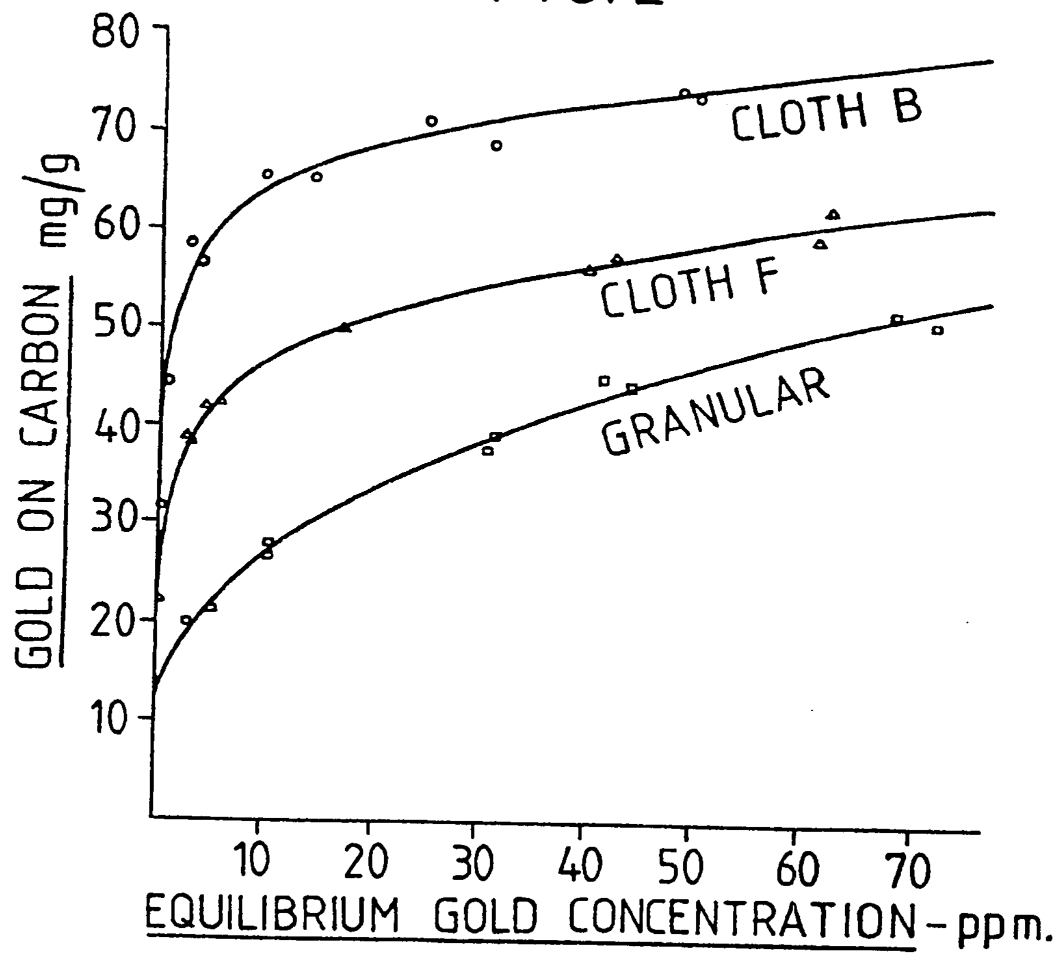
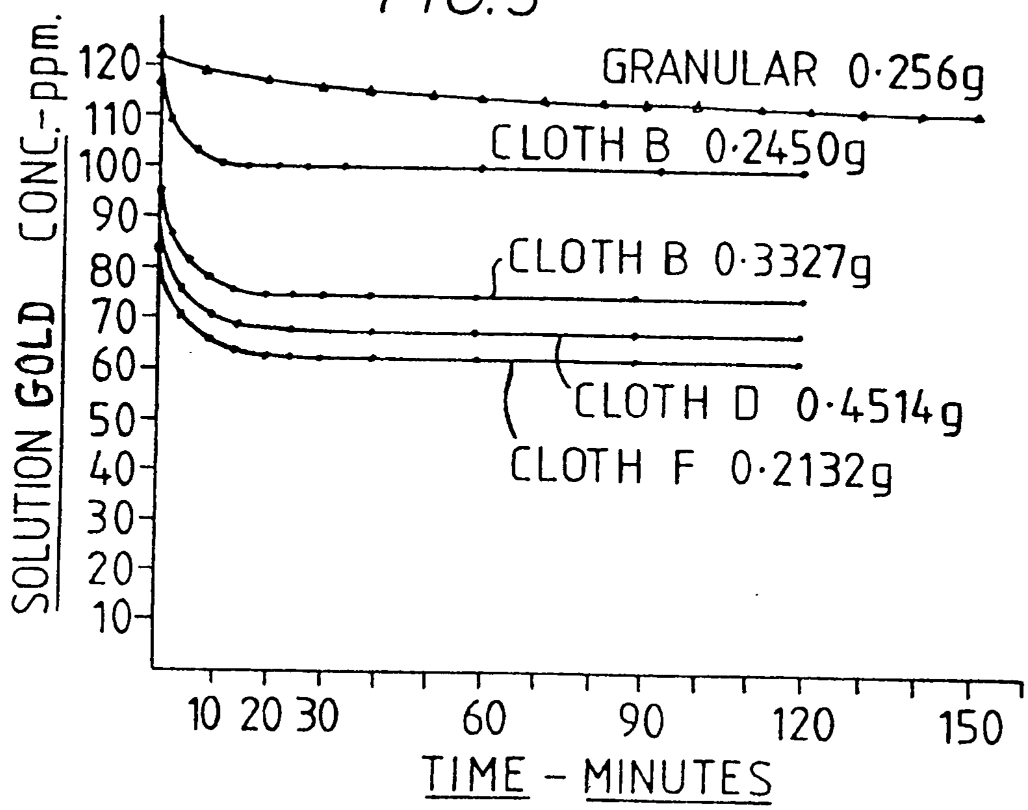
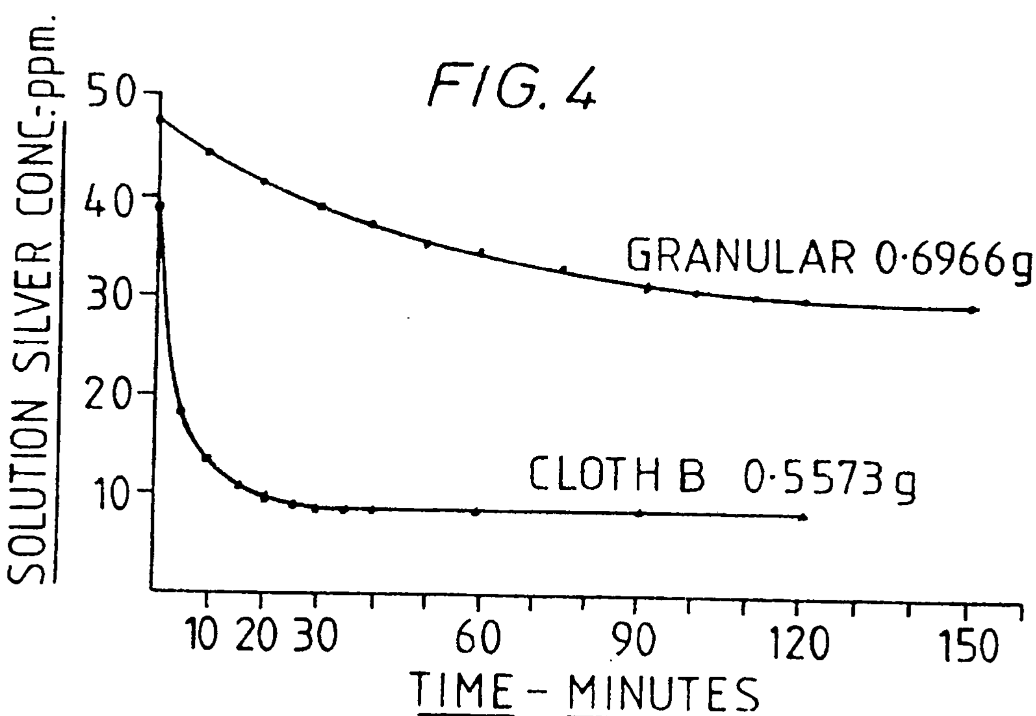

80
70
60
50
40
30
20
10
GOLD ON CARBON mg/g
CLOTH B
CLOTH F
GRANULAR
10
20
30
40
50
60
70
EQUILIBRIUM GOLD CONCENTRATION - ppm.

FIG. 3



SOLUTION GOLD CONC.-ppm.
120
110
100
90
80
70
60
50
40
30
20
10
GRANULAR 0·256g
CLOTH B 0·2450g
CLOTH B 0·3327g
CLOTH D 0·4514g
CLOTH F 0·2132g
10 20 30
60
90
120
150
TIME - MINUTES

FIG. 4



SOLUTION SILVER CONC.-ppm.
50
40
30
20
10
GRANULAR 0·6966g
CLOTH B 0·5573g
10 20 30
60
90
120
150
TIME - MINUTES

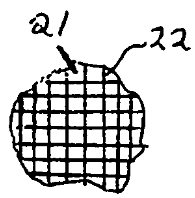


FIG. 5

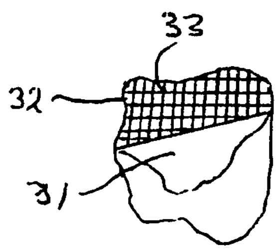


FIG. 6

SPECIFICATION

Recovery of precious metal(s)

This invention relates to recovering precious metal(s) from solution(s) containing dissolved precious metal compound(s) especially but not exclusively comprising gold.

Ore bodies or other materials containing metallic gold can be leached with dilute cyanide solutions so as to obtain liquor containing dissolved gold compound(s). Such a liquor can also contain dissolved compound(s) of other precious metal(s), e.g. silver and/or platinum group metals e.g. palladium. One known process for recovering gold from such a liquor comprises adding at least one base metal (e.g. zinc) to the liquor so as to precipitate gold as metal particles. Particles of other precious metal(s) can also precipitate with the gold particles. Another known process for recovering gold from the liquor comprises an adsorption stage and a stripping stage. In the adsorption stage, particles of activated carbon (i.e. granular activated carbon) are contacted with the liquor so that dissolved compound(s) of gold are adsorbed onto those particles. Dissolved compound(s) of other precious metal(s) can also be adsorbed onto those particles. In the stripping stage, the resultant particles of carbon loaded with adsorbed gold compound(s), and any adsorbed compound(s) of other precious metal(s), are treated with a liquid stripping composition comprising cyanide(s), so as to give a solution containing dissolved gold compound(s), and optionally dissolved compound(s) of other precious metal(s). The stripping composition may be a hot, dilute aqueous mixture of sodium hydroxide and sodium cyanide. The adsorption and stripping stages can be carried out in columns or vats and are slow. Also, because the physical nature of the granular particles of activated carbon, those stages can be labour intensive. A further problem is that pieces of carbon can break off from the bulk of activated carbon and cause gold loss in the adsorption stage, especially given that the granular activated carbon is often prepared from wood or coconut husks. Particles of carbon obtained from the stripping stage can be reactivated by heating them (e.g. at 650 to 750°C), usually in the absence of air. They may then be re-used in the adsorption stage. The solution obtained from the stripping stage can be further processed, e.g. in an electrolytic stage using a suitable cathode (e.g. steel cathode(s) optionally as steel wool) onto which metallic gold is deposited and from which it may be recovered.

A first aspect of the present invention provides a process for recovering, as metal or as a compound thereof, at least one precious metal (preferably gold) from a solution of at least one dissolved compound of that precious metal, said process comprising: at least one adsorption stage for adsorbing onto activated carbon at least one precious metal compound from said solution, wherein said activated carbon is in the form of at least one fibrous body comprising fibres of activated carbon so that said fibrous body becomes at least partly loaded with said adsorbed at least one precious metal compound, said loaded fibrous body being optionally treatable in at least one stripping stage (see later herein), and optionally in at least one said adsorption stage, at least one said fibrous body has at least one substrate.

An optional substrate for at least one said fibrous body can be provided in any suitable manner and serve at least one purpose. Examples of such purposes are:

(a) *Locate a fibrous body.* For instance, a substrate could be a prelocated web on which at least one fibrous body is removably or permanently laid. A substrate could be a location support in a filter press.

(b) *Support a fibrous body.* For instance, a substrate could be a web to which at least one fibrous body is permanently or removably bonded. Such bonding could result from applying heat and/or pressure to an assembly of at least one fibrous body and a suitable substrate (e.g. a substrate having adhesive property(s) activated by heat and/or pressure, for instance at least one thermoplastic layer). The bonding could utilise suitable adhesive not part of a substrate.

(c) *Strengthen a fibrous body.* For instance, a substrate can be a reinforcement web (e.g. of suitable cloth comprising fibres of natural and/or synthetic origin) for at least one fibrous body.

(d) *Enable assembly(s) or composite(s) to be provided.* It will be appreciated that purposes (b) and (c) above can be utilised to provide assembly(s) or composite(s) of any suitable kind, e.g. an assembly or composite in which opposite faces of a substrate (e.g. a web of cloth or of mesh) are respectively positioned adjacent or bonded to first and second said fibrous bodies, those bodies preferably being woven cloths. Thus, singly or plural ply porous bodies can be made.

The substrate can be embodied in any suitable manner. For example, the substrate can have at least one pore having an inlet, and optionally an outlet to enable communication between opposite faces of the substrate. Any said pore can have any suitable geometrical characteristics, e.g. shape/size of inlet, shape/size of outlet, and depth of pore. Any plurality of said pores can comprise at least two identical pores and/or at least two different pores. Such a plurality can be disposed in any suitable manner. Pore(s) can be made in any suitable manner, e.g. in a weaving, moulding, or piercing process. The substrate can be at least partly electrically insulating or at least partly electrically conductive. An example of an electrically insulating substrate is a suitable organic polymeric substrate, e.g. a thermoplastic for instance a polyvinylchloride. Examples of an

electrically conductive substrate are a metal substrate or a matrix of electrically insulating polymeric material containing particles of carbon. By choice of material(s) for a said substrate, the substrate can be enabled to have any suitable electrical property(s). A suitable substrate could serve as an anode in a stripping stage (see later below), for instance substrate that could be separated from the fibrous body after electrolysis has caused precious metal to be deposited on and/or in that substrate. The substrate can be adsorbant e.g. to electrolyte.

Precious metal solution(s) to be subjected to the first aspect of the present invention can be provided and utilised in any suitable manner. One example of such a solution can be obtained by leaching an ore or other suitable material. Ore leaching can be carried out at a mine or other location for example at a gold mine.

The fibrous body(s) can have any suitable structure, e.g. it may be woven, knitted, or felt. A fibrous body can be a fabric, mesh or pad, for example. Preferably, at least one said fibrous body is a cloth consisting of fibres containing substantially 100% by weight of activated carbon. A cloth of fibres of activated carbon termed "Charcoal Cloth" is a known fabric available from Charcoal Cloth Limited. That cloth is manufactured by a continuous process developed and patented by the Chemical Defence Establishment of the British Government. The process permits the manufacture of a flexible fabric consisting of highly adsorbent fibres which are substantially 100% by weight activated carbon. Reference is made to British Patents 1301101, 1310011 and 1376888 in connection with that fabric. One example of the preparation of a Charcoal Cloth is a process comprising: dipping a rayon cloth in chemicals; drying the dipped cloth; carbonising the dried cloth at 350°C; and heating the carbonised cloth at 900°C to activate it. When, in accordance with the present invention, a cloth of fibres of activated carbon is contacted with a solution of a precious metal, the cloth presents greater surface area to the solution per unit weight of carbon, and considerably higher quantities of precious metal, e.g. gold compound(s), can be adsorbed, contrasted with known adsorption using particles of activated carbon. A further advantage of the cloth is that it will require less handling than particles of activated carbon, and there will be considerable reduction in pieces of carbon breaking away from the main bulk of carbon. Indeed, the nature of the cloth can act as a trap to retain at least some of those pieces. Thus, the cloth can have a longer useful life than granular activated carbon. The cloth can enable simplified recovery of precious metal(s). In general, the cloth can be disposed and/or embodied in at least one configuration, e.g. for remaining stationary during use or for moving during use. The cloth can be present in at least one path, e.g. a path that is an open or closed figure.

A second aspect of the present invention comprises: at least one stripping stage for at least partly removing adsorbed metal compound(s) from at least one said loaded fibrous body; and optionally at least one said stripping stage is adapted to provide metallic precious metal(s) from at least one said adsorbed metal compound and/or from at least one said stripped adsorbed metal compound (see later below).

In the second aspect of the invention, at least one said stripping stage can comprise contacting at least one said loaded body with at least one liquid stripping composition so as to give a solution comprising dissolved, stripped precious metal compound(s), e.g. a dissolved gold compound. The stripping composition can comprise at least one solute and/or at least one solvent. Preferably, at least one said stripping composition comprises aqueous solution of at least one cyanide. Such a solution preferably comprises sodium hydroxide and sodium cyanate. A said stripping solution can be used under any suitable operating condition(s), e.g. of temperature. Precious metal(s) can be obtained from a said solution by any known work-up technique.

In the second aspect of the invention, at least one said stripping stage can comprise subjecting at least one said loaded body to electrolysis. For example, a loaded body can conduct electricity and be used as an anode in cathodic deposition of metal. An example of a cathode for that use is steel wire or steel wool. A further example of a cathode is a suitable said substrate. The nature of metallic precious metal obtained by said electrolysis will depend on e.g. current density, for instance gold can be formed as a bright metal plating or as a granular deposit on a said cathode or in said electrolyte. It should be noted that processes of the prior art using beds of granular active carbon in recovering precious metal(s) were not suitable for use as anodes. Thus, those beds could not have been subjected to at least one stripping stage using electrolysis, and other treatment stage(s) were needed.

In the present invention, at least one said fibrous body can be mounted in a filter press, so as to be contactable with precious metal(s) solution in at least one said adsorption stage. That mounting enables the fibrous body(s) to be conveniently subjected in situ to at least one said stripping stage. In a cyclic application of the invention, at least one said fibrous body can be used in the form of a belt (preferably an endless belt) movable through at least one adsorption stage to and through at least one said stripping stage and then back to said at least one adsorption stage, and the cycle repeated if desired. This cycling is applicable to utilising at least one said stripping composition, or to stripping using at least one said electrolysis. An endless belt permits e.g. a continuous process.

A third aspect of the present invention comprises at least one activation stage for at least one said fibrous body, before at least one said adsorption stage, and/or after at least one said

stripping stage, at least one said activation stage comprising heating at least one said fibrous body to at least one sufficient temperature (e.g. in an oven) so as e.g. to remove at least some surface contamination (if any is present) from at least one said fibrous body and/or to generate or enhance adsorption activity of at least one said fibrous body. One example of said heating is to a temperature of substantially 250°C.

In carrying out the invention, said stripping can be done in at least one step, and said activation can be done in at least one step. At least some activation can be done after all of said stripping. For a typical gold mine leaching operation, the present invention can enable adsorption stage(s) and stripping stage(s) to take place quickly and thereby provide better overall efficiency. Gold recovered can be present with or without other precious metal(s).

The invention is illustrated with reference to the following examples and also to the accompanying drawings, wherein:

Figure 1 is a schematic representation of a continuous process according to the invention.

Figures 2 to 4 are graphs in which the performance of activated carbon cloths is compared with that of granular activated carbon.

Figure 5 shows a single ply of activated carbon cloth on a mesh substrate.

Figure 6 shows a sandwich composite of activated carbon cloths.

Example 1 (see Figure 1)
Gold recovery utilising electrolysis

In Fig. 1, an endless woven web W of a Charcoal Cloth (see above) extends in a path contacting a variable drive roller 1 and rollers 2 to 14. Rollers 2, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14 are plastics (e.g. nylon) rollers. Rollers 3 and 5 are positively charged. A first portion of the web's path is through Chamber A, containing any suitable cathode 15 (e.g. steel) and electrolyte. Chamber A is used for subjecting to electrolysis the Charcoal Cloth when loaded with at least one adsorbed gold compound, the metallic gold being deposited onto cathode 15. Chamber B contains an aqueous wash bath for the web. Chamber C contains a liquor obtained by treating a gold containing ore with a leaching composition comprising sodium hydroxide, sodium cyanide, and water. Chamber D contains a further aqueous wash bath for the web. Any chamber can be replaced by a plurality of chambers, to allow plural treatments. The web, after electrolysis, can pass through an optional oven 16 between chambers B and C, which reactivates the web by heating.

The Charcoal Cloth web can be a single ply or a plurality of plies, e.g. a sandwich construction of two single plies of Charcoal Cloth separated by and bonded to a mesh substrate (see later below).

Example 2 (see Figure 2)
Equilibrium adsorption trials—gold

The adsorption capacity of two activated carbon fibre cloths was compared with granular activated carbon. The cloths were purchased from Charcoal Cloth Limited and had the following weights per unit area:

Cloth B	12.4 mg/cm^2
Cloth D	12.9 mg/cm^2
Cloth F	14. 5 mg/cm^2

Cloth discs of 2 cm diameter were used in the tests.

A number of gold solutions were prepared from pure gold potassium cyanide at strengths calculated to produce equilibrium concentrations in the range 0 to 75 ppm. gold. Discs of Cloths B and F were placed in contact with the gold solutions in plastic containers and mechanically agitated for 48 hours. Samples of granular activated charcoal were similarly treated. The results depicted graphically in the accompanying Figure 2 were obtained. Figure 2 shows equilibrium adsorption isotherms indicating that at any particular equilibrium gold concentration, the uptake of gold achieved by the cloths is greater than that by the granular activated charcoal. This effect is particularly marked in the low concentration ranges which are most likely to be found in industrial applications.

Example 3 (see Figure 3)
Kinetic trials—gold

As in Example 2, gold solutions of various concentrations were prepared from potassium gold cyanide. 700 ml of start solutions were used. Pieces of the cloths B, D and F weighing between 0.2 and 0.5 g were held in a sintered glass crucible. Temperature was held at 21°C throughout and pH at 10.5. Gold solutions were circulated through the cloth samples and 5 ml samples were withdrawn at intervals of 5 minutes. Gold concentrations were determined by atomic absorption spectra. Granular activated charcoal was similarly treated. The results shown graphically in the accompanying Figure 3 were obtained. The rates of adsorption using the cloth samples were extremely fast. Steady state conditions were reached after 20 to 25 minutes. With the granular activated charcoal, much less adsorption and a much slower adsorption rate were found. In order to magnify these effects, a test was carried out in which a relatively large sample (2.56 g) of granular activated charcoal was used. This test took about 2-1/2 hours to reach equilibrium. Because the adsorption rate of the cloths is greater it follows that a lesser quantity of activated carbon in this form is required to be in contact with the solution at any given time.

Example 4 (see Figure 4)
Kinetic trials—silver

Example 3 was repeated with a sample of Cloth B and granular activated charcoal, using solutions obtained from silver potassium cyanide instead of gold. The results are set out graphically in the accompanying Figure 4 and prove similar to

Example 3 in establishing the superiority of the cloth. This cloth adsorbed more silver than the granular activated charcoal and reached equilibrium more quickly, again in about 20 to 25 minutes as compared with 2-1/4 to 2-1/2 hours.

Example 5
Electrolytic recovery—gold

A sample of Charcoal Cloth was contacted for 2 hours with a solution of gold cyanide. At the end of this period the cloth had adsorbed 55.20 mg gold. The cloth was then used as an anode in an electrolyte containing 1.0% by wt NaOH and 0.1% NaCN. A pre-weighed titanium cathode was also placed in the electrolyte. A DC current was passed for 45 minutes and was equivalent to a current density on the carbon cloth anode of 10 amps/ft^2 (substantially 100 amps/m^2). At the end of the trial, the electrolyte was found to contain 0.45 mg gold and 35.9 mg gold had deposited onto the cathode. This experiment shows that gold can be removed from the cloth at low DC current densities and deposited electrolytically onto a suitable cathode.

Example 6
Electrolytic recovery—gold—high current density

A sample of Charcoal Cloth was contacted for 2 hours with a solution of gold cyanide. At the end of this period, the cloth had adsorbed 28.05 mg gold. The cloth was then used as an anode in an electrolyte containing 1.0% by wt NaOH and 0.1% NaCN. A titanium cathode was also placed in the electrolyte. The cloth anode and the cathode were electrically connected to a DC power source. A DC current was passed equivalent to a current density on the carbon cloth anode of 100 amps/ft^2 (substantially 1000 amps/m^2) for 5 minutes. No gold could be detected on the cathode, but 4.18 mg gold were found to be dissolved in the electrolyte. A fine powder was formed in the electrolyte. The powder, when filtered off and redissolved, was found to contain 1 mg gold. This experiment shows that at relatively high DC current densities, gold can be swiftly removed from the cloth.

Example 7 (see Figure 5)
Sandwich charcoal cloth

In Figure 5, a single ply 21 of Charcoal Cloth is bonded to one face of a mesh substrate 22 made of suitable material to permit said bonding to be provided by application of heat and/or pressure, and optionally with adhesive.

Example 8 (see Figure 6)
Two ply charcoal cloth

In Figure 6, two plies 31 and 32 of Charcoal Cloth are respectively bonded to opposite faces of a mesh substrate 33 made of any suitable material to permit said bonding to be provided by application of heat and/or pressure, and optionally with adhesive not part of the mesh substrate 23.

The above Examples and the drawings accompanying this specification can be modified in accordance with the general description given above before the first reference to the accompanying drawings. For example, any suitable pH's could be used. A Charcoal Cloth can have any suitable weave. A said substrate can be constituted in at least one manner from at least one material, e.g. a web can be of fibres (e.g. threads or filaments). In general, a web can be embodied in any suitable manner and be used in any suitable manner, e.g. provided or supported by at least one means. A substrate can be adapted to be used at least once. In general, fibres can be constituted in any suitable manner for a said fibrous body or a said fibrous substrate. e.g. comprise at least one thread or filament, and have twist or no twist. A said substrate can be a network of e.g. polymeric material (for instance a thermoplastic) or of metal threads. Such a network can be provided in any suitable manner, e.g. as a preformed mesh or a mesh formed in situ by application of e.g. polymeric material to surface of at least one said fibrous body.

Claims (Filed on 28/3/83)

1. A process for recovering, as metal or as a compound thereof, at least one precious metal from a solution of at least one dissolved compound of that precious metal, said process comprising:

at least one adsorption stage for adsorbing onto activated carbon at least one precious metal compound from said solution, wherein said activated carbon is in the form of at least one fibrous body comprising fibres of activated carbon so that said fibrous body becomes at least partly loaded with said adsorbed at least one precious metal compound; and optionally in at least one said adsorption stage, at least one said fibrous body has at least one substrate.

2. A process as claimed in claim 1, wherein said precious metal is gold.

3. A process as claimed in claim 1 or 2, wherein said solution has been obtained by leaching an ore or other suitable material.

4. A process as claimed in claim 3, wherein said solution has been obtained by leaching an ore at a mine or other location.

5. A process as claimed in any one of claims 1 to 4, wherein said fibrous body is a cloth consisting of fibres containing substantially 100% by weight of activated carbon.

6. A process as claimed in claim 5, wherein said cloth is charcoal cloth.

7. A process as claimed in any one of claims 1 to 6, wherein in at least one said adsorption stage, at least one said fibrous body has at least one said substrate.

8. A process as claimed in claim 7, wherein at least one said substrate is adapted to locate at least one said fibrous body.

9. A process as claimed in claim 7 or 8, wherein at least one said substrate is adapted to support at least one said fibrous body.

10. A process as claimed in any one of claims

7 to 9, wherein at least one said substrate is adapted to strengthen at least one said fibrous body.

11. A process claimed in any one of claims 7 to 10, wherein there is at least one assembly or at least one composite, said assembly or said composite comprising at least one said substrate and at least one said fibrous body.

12. A process as claimed in claim 11, wherein there is a said assembly or said composite in which opposite faces of a said substrate are respectively positioned adjacent or bonded to first and second said fibrous bodies.

13. A process as claimed in any one of claims 7 to 12, wherein at least one said substrate has at least one pore.

14. A process as claimed in claim 13, wherein at least one said substrate is a mesh.

15. A process as claimed in any one of claims 7 to 14, wherein at least one said substrate is at least partly electrically insulating.

16. A process as claimed in any one of claims 7 to 15, wherein at least one said substrate is at least partly electrically conductive.

17. A process as claimed in claim 16, wherein at least one said electrically conductive substrate is an anode for a stripping stage.

18. A process as claimed in any one of claims 1 to 17, comprising at least one stripping stage for at least partly stripping adsorbed metal compound(s) from at least one said loaded fibrous body, and optionally at least one said stripping stage is adapted to provide metallic precious metal(s) from at least one said adsorbed metal compound and/or from at least one said stripped adsorbed metal compound.

19. A process as claimed in claim 18, wherein at least one said stripping stage comprises contacting at least one said loaded body with at least one liquid stripping composition so as to give a solution comprising dissolved stripped precious metal compound(s).

20. A process as claimed in claim 19, wherein said stripping composition comprises at least one solute and/or at least one solvent.

21. A process as claimed in claim 20, wherein at least one said stripping composition comprises aqueous solution of at least one cyanide.

22. A process as claimed in claim 21, wherein said aqueous solution comprises sodium hydroxide and sodium cyanide.

23. A process as claimed in any one of claims 18 to 22, wherein at least one said stripping stage comprises subjecting at least one said loaded body to electrolysis.

2. A process as claimed in claim 23, wherein a said loaded body is an anode in cathodic deposition of at least one said precious metal.

25. A process as claimed in claim 23 or 24, when according to claim 16, wherein a said electrically conductive substrate is an anode.

26. A process as claimed in any one of claims 1 to 25, wherein at least one said fibrous body is mounted in a filter press, so as to be contactable with precious metal(s) solution in at least one said adsorption stage.

27. A process as claimed in any one of claims 18 to 25, wherein for cyclic application of said process at least one said fibrous body is in the form of a belt movable through at least one adsorption stage to and through at least one said stripping stage and then back to said at least one adsorption stage, and that cycle is optionally repeated.

28. A process as claimed in claim 27, wherein said belt is an endless belt.

29. A process as claimed in any one of claims 1 to 28, comprising at least one activation stage for at least one said fibrous body, before at least one said adsorption stage, and/or after at least one said stripping stage, at least one said activation stage comprising heating at least one said fibrous body to at least one activation temperature for enabling said activation.

30. A process as claimed in claim 29, wherein said heating is to a temperature of substantially 250°C.

31. A process as claimed in claim 1, substantially as hereinbefore described with reference to the accompanying drawings.

32. A process as claimed in claim 1, substantially as hereinbefore described with reference to Example 1.

33. A process as claimed in claim 1, substantially as hereinbefore described with reference to Example 2.

34. A process as claimed in claim 1, substantially as hereinbefore described with reference to Example 3.

35. A process as claimed in claim 1, substantially as hereinbefore described with reference to Example 4.

36. A process as claimed in claim 1, substantially as hereinbefore described with reference to Example 5.

37. A process as claimed in claim 1, substantially as hereinbefore described with reference to Example 6.

38. A process as claimed in claim 1, substantially as hereinbefore described with reference to Example 7.

39. A process as claimed in claim 1, substantially as hereinbefore described with reference to Example 8.

40. A precious metal or a compound thereof, recovered by a process as claimed in any one of claims 1 to 39.

41. Apparatus for carrying out a process as claimed in any one of claims 1 to 40, wherein said apparatus comprises:

means for constituting said at least one adsorption stage; and said at least one fibrous body for said at least one adsorption stage.

42. Apparatus as claimed in claim 41,

comprising means for constituting said at least one stripping stage.

43. Apparatus as claimed in claim 41, substantially as hereinbefore described with reference to and as shown in Figs. 1, 5, and 6 of the accompanying drawings.

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